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ABSTRACT. The results of a study on the inhomogeneity of quartz crystals by x-ray diffraction topographic methods are discussed. The resulting data are then compared with optical data. The study was performed with natural and artificial quartz crystals using a specially fabricated Lang camera. Two types of inhomogeneities are described: striae and banding. The authors conclude that striation is caused by dislocations and that banding may be attributed to the fact that the chemical nature of the complexes which precipitate on the crystal changes in the course of crystal growth as a result of fluctuation of the technical conditions.

It is well known that optical methods [1, 2] are used in detecting differ- /585* ent inhomogeneities of quartz crystals (striae, sectorality, banding, etc., Figure 1a). The nature of these defects and the mechanism of their formation in the course of crystal growth has not been finally clarified, but it may be considered firmly established that they are related to the trapping of impurities from the initial solution and fluctuations of the thermodynamic parameters in the course of crystal growth [3]. Also remaining unclarified are problems as to the type of macrodisruptions of the crystal structure associated with the inhomogeneities detected by optical methods (Figures 1-3, see insert to page 555).**

The purpose of this report is to discuss the results of a study on the inhomogeneity of quartz crystals by x-ray diffraction topographic methods and to compare the resulting data with optical data. A study was made of natural and artificial quartz crystals using a specially fabricated Lang camera [4, 5].

Striae and their relationship to dislocations. Figure 1c shows a diffractogram with a crystal of artificial quartz in which strong striation was optically detected. Comparison of Figures 1a and 1c shows that topographic methods reveal a picture of inhomogeneities of a quartz crystal very similar to the optical picture, but these pictures also have differences.

The sharply defined lines in Figure 1c are due to the contrast from dislocations. This also is confirmed by a comparison with data on the etching of quartz crystals by fluoric acid. It was demonstrated in [6] that dislocations emerging onto the base plane are manifested in the form of etching pits and channels penetrating deep into the crystal. Figure 1b shows a picture of the etching of a quartz crystal from which the diffractogram shown in Figure 1c was obtained, which convincingly substantiates the conclusion expressed above.

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*Numbers in the margin indicate pagination in the foreign text.
**Reference is made to original Russian text.

Proceeding on the basis of concepts on the dislocation mechanism of the growth of a quartz crystal, it may be expected that these dislocations will be helical dislocations with the Burgers vector directed along the optical axis. Then, however, they would not be observed in Figure 1c due to the condition of detection of dislocations by the topographic method [7]. Thus, the Burgers vector of these dislocations has a component perpendicular to the optical axis of the crystal. Let us also note that these dislocations are not of the pure helical type, because under certain photographic conditions the rosettes caused by them are detected (Figure 2).

We plan to make a more complete analysis of dislocations in quartz crystals, the subject of our preceding report. Considering the objective of this report, we will limit ourselves only to the conclusion that the optical inhomogeneity of artificial quartz crystals, called striation, is caused by dislocations.

The following statements may be made as to the cause of the relationship between the considered dislocations and this optical inhomogeneity: the dislocations, in the course of crystal growth, capture a large amount of impurity and, in addition, create favorable conditions for the formation of Suzuki atmospheres around them. As a result of this enrichment with impurity atoms (or complexes), regions with a high density of dislocations are detected as optical /586 inhomogeneities (striae).

Let us note that the enhanced capacity of the considered dislocations for capture of impurity atoms (or entire complexes) indicates that they have a special character. Obviously, they differ from dislocations from which crystal growth results. We feel that these dislocations are of the *hollow* type [3, 8].*

Figure 1 makes it possible to draw conclusions concerning the origin of these dislocations. These dislocations [6] are either a continuation of dislocations from etching in the growing crystal or they arise in microscopic inclusions.

Banding in quartz crystals. Figures 1a and 1b also show another type of inhomogeneity of artificial quartz crystals known as banding. The crystal contains bands which differ from one another in the concentration of the trapped impurity and, therefore, in the refractive index (this explains the banding in Figure 1a) and also the lattice parameters, which cause the banding visible in Figure 1c.

We feel that the banding of crystals may be attributed to the fact that in the course of their growth, as a result of fluctuation of the technical conditions of crystal growth, there is a change of the chemical nature of the complexes precipitating on the crystal [9]. For example, in the normal growth of crystals there is a precipitation of SiO_2 molecules, while in fluctuations of the growth regime, more complex polymer complexes of SiO_2 containing a varying quantity of the impurity are precipitated.

*Translator's italics.

A banded structure also is detected by the topographic method in crystals of natural quartz (Figure 3). Our attempts to detect this type of banding by the optical method were a failure. The banding of natural quartz crystals obviously has the same origin as in artificial crystals and is due to a difference in the crystal structure of the layers as a result of a change in the physical and chemical conditions of growth.

Figure 3 shows that the x-ray topography method clearly reveals the sectorial and zonal structure of the quartz crystals, which makes it possible to reestablish the conditions of their growth.

Let us note in conclusion that this study was undertaken on the initiative of A. M. Yelistratov. The authors feel it their pleasant duty to express appreciation to I. L. Shul'pina and O. N. Yefimov, students of A. M. Yelistratov, for their assistance in learning the procedures and their useful discussions.

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